

# **INDOOR AIR QUALITY ASSESSMENT**

**Julia Bancroft Elementary School  
3 Vinal Street  
Auburn, Massachusetts**



Prepared by:  
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May 2004

## **Background/Introduction**

At the request of Mr. Rocco Morano, School Principal, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Julia Bancroft Elementary School (JBES), 3 Vinal Street, Auburn, Massachusetts. On January 8, 2004, Cory Holmes, Environmental Analyst, Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an indoor air quality assessment.

The JBES is a two-story, red brick building constructed in 1917. The basement of this original building is occupied. A one-story addition was built in 1956 and in 2002, two modular classroom units were added. A hallway connects the 1956 wing and modular units to the original 1917 building. Windows in both buildings were reportedly replaced twelve years ago and are now in disrepair, leaving many of them unopenable or difficult to open. The original 1917 building and the 1956 wing contain separate ventilation systems that function independently of one another. Because the buildings have independent ventilation systems, they are the subject of separate reports. This report discusses findings at the JBES 1917 building.

## **Methods**

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were taken with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

## **Results**

The 1917 building houses grades three and four, with a student population of approximately 100 and a staff of approximately 20. Tests were taken under normal operating conditions and results appear in Table 1.

## **Discussion**

### **Ventilation**

It can be seen from the Table 1 that carbon dioxide levels were elevated above 800 parts per million parts of air (ppm) in eight of ten areas surveyed, indicating inadequate air exchange in most areas of the school on the day of the assessment. Two areas that did not have elevated carbon dioxide levels were also sparsely populated, which can greatly reduce carbon dioxide levels. In addition, several areas that were not occupied had elevated carbon dioxide levels.

Fresh air in classrooms of these sections of the building was originally supplied by a unit ventilator (univent) system (Picture 1). Univents are designed to draw air from outdoors through a fresh air intake located on the exterior walls of the building (Picture 2) and return air through an air intake located at the base of each unit ([Figure 1](#)). Fresh and return air are mixed, filtered, heated and provided to classrooms through a fresh air diffuser located in the top of the unit. Univents appear to be original equipment, approximately 80 years old. Function of such aged equipment is difficult to maintain, since compatible replacement parts are often unavailable. Due to the age of the equipment, univents were not operating at the time of the assessment. As a result, no mechanical means for providing fresh air to classrooms exists.

The speech and library located in the basement have neither windows nor mechanical or passive ventilation for air exchange. A fresh air source is necessary for the dilution of indoor air pollutants.

Exhaust vents in the original building are located in coat closets (Pictures 3 and 4) or in ungrated “cubby holes” located at floor level in classrooms (Picture 5). Classroom air is drawn into the coat closet via an undercut below the closet door. Both these exhaust designs allow for the vents to be easily blocked by stored materials (Pictures 4 and 5). In order to function properly, these vents must remain free of obstructions.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last balancing of these systems was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The mechanical ventilation system, in its current condition, cannot be balanced.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches ([Appendix A](#)).

Temperature readings ranged from 70° F to 77° F, which were within the BEHA recommended comfort guidelines during the assessment. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. Temperature complaints were expressed in a number of areas. As discussed previously, windows in the building are difficult to operate. A number of classrooms had windows that could not be completely closed (Picture 6) allowing for drafts. Temperature control is often difficult in a building with abandoned or nonfunctioning ventilation systems and original loose fitting window frames (see discussion under Microbial/Moisture Concerns section). In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity ranged from 16 to 22 percent, which was below the BEHA recommended comfort range in all areas. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Humidity is more difficult to control during the winter heating season. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

### **Microbial/Moisture Concerns**

Windows in a number of classrooms do not close completely (Picture 6), allowing for drafts and moisture penetration. Repeated water damage can result in mold colonization of wooden window frames and porous materials. Once mold has colonized these materials, they are difficult to clean and should be replaced.

Efflorescence was observed on the walls of classrooms near univents (Picture 7). Efflorescence is a characteristic sign of water damage to building materials such as brick or plaster, but it is not mold growth. As moisture penetrates and works its way through mortar around brick, water-soluble compounds dissolve, creating a solution. As the solution moves to the surface of the brick or mortar, water evaporates, leaving behind white, powdery mineral deposits. This condition indicates that water from the exterior has penetrated into the building.

Plants were noted in several classrooms. Plants can be a source of pollen and mold, which can be respiratory irritants for some individuals. Plants should be properly maintained and equipped with drip pans. Plants should also be located away from univents to prevent the aerosolization of dirt, pollen or mold.

A number of areas had water-stained ceiling tiles, which can indicate leaks from the roof or plumbing system. Water-damaged porous building materials can provide a source for mold and should be replaced after a water leak is discovered and repaired.

### **Other Concerns**

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants; however, the pollutant produced is dependent on the material combusted. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers ( $\mu\text{m}$ ) or less (PM<sub>2.5</sub>) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM<sub>2.5</sub>. Outdoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured in the school were also ND.

Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions of reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC

systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000).

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. *Carbon monoxide should not be present in a typical, indoor environment.* If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels.

The NAAQS originally established exposure limits for particulate matter with a diameter of 10  $\mu\text{m}$  or less (PM<sub>10</sub>). According to the NAAQS, PM<sub>10</sub> levels should not exceed 150 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) in a 24-hour average. This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM<sub>2.5</sub> standard requires outdoor air particulate levels be maintained below 65  $\mu\text{g}/\text{m}^3$  over a 24-hour average. Although both the ASHRAE standard and BOCA Code adopted the PM<sub>10</sub> standard for evaluating air quality, BEHA uses the more protective proposed PM<sub>2.5</sub> standard for evaluating airborne particulate matter concentrations in the indoor environment. Outdoor PM<sub>2.5</sub> concentrations were measured at 7  $\mu\text{g}/\text{m}^3$  (Table 1). PM<sub>2.5</sub> levels measured indoors ranged from



8 to 23  $\mu\text{g}/\text{m}^3$ . Although PM<sub>2.5</sub> measurements were above background in some areas, they were below the NAAQS of 65  $\mu\text{g}/\text{m}^3$ . Frequently, indoor air levels of particulates (including PM<sub>2.5</sub>) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were non-detect (ND) (Table 1). Indoor TVOC measurements throughout the building were also ND.

Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use TVOC containing products (e.g., the concentration of TVOCs within a classroom increases when the product is in use).

The art room contained an unvented kiln (Picture 8). Kiln exhaust may produce corrosive, hazardous and irritating materials including chlorine, sulfur dioxide and carbon

monoxide. Pottery kilns should be provided with dedicated local exhaust ventilation (McCann, 1985) to ventilate these possible emissions from the interior of the building.

Accumulated chalk dust (Picture 9) and dry erase markers were seen in several classrooms. Chalk dust is a fine particulate, which can become easily aerosolized and serve as a source of eye and respiratory irritation. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, (e.g. methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999).

Cleaning products were found on countertops and in unlocked cabinets beneath sinks in some classrooms (Picture). Like dry erase materials, cleaning products contain VOCs and other chemicals that can be irritating to the eyes, nose and throat of sensitive individuals.

Several other conditions that can affect indoor air quality were noted during the assessment. Exposed fiberglass insulation was noted around pipes in classrooms (Picture 10). Fiberglass insulation can be a source of skin, eye and respiratory irritation to sensitive individuals.

Also of note was the amount of materials stored inside classrooms. In several areas, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate (Picture 11). These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Dust can be irritating to the eyes, nose and respiratory tract. For this reason, items should be relocated and/or cleaned periodically to avoid excessive dust build up.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and to off-gas TVOCs.

Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as [Appendix B](#) (NIOSH, 1998).

## Conclusions/Recommendations

The conditions related to indoor air quality problems at the JBES raise a number of issues. The general building conditions, maintenance, work hygiene practices and the condition of HVAC equipment, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further negatively affect indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons a two-phase approach is required, consisting of **short-term** measures to improve air quality and **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for immediate implementation:

1. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the operability of univents.
2. Discontinue use of kiln until local exhaust ventilation can be provided. Local exhaust should be ducted directly to the outdoors.

3. Use openable windows in conjunction with classroom exhaust vents to create air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
4. Remove all blockages from exhaust vents to ensure adequate airflow.
5. Operate all ventilation systems that are operable throughout the building (e.g., gym, auditorium, classrooms) continuously during periods of school occupancy independent of thermostat control to maximize air exchange.
6. Install a passive vent in the door to the speech room and library to provide air exchange.
7. Adopt scrupulous cleaning practice. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
8. Ensure leaks are repaired and replace water damaged ceiling tiles. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
9. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary. Keep plants away from the air stream of univents.

10. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning of classrooms. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
11. Encapsulate exposed pipe insulation to avoid the aerosolization of fiberglass fibers.
12. Clean chalkboard/dry erase marker trays regularly to prevent the build-up of excessive chalk dust and particulate.
13. Store cleaning products properly and out of reach of students.
14. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation.
15. Consider adopting the US EPA document, “Tools for Schools”, to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: <http://www.epa.gov/iaq/schools/index.html>.
16. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH’s website at <http://www.state.ma.us/dph/beha/iaq/iaqhome.htm>.

The following **long-term measures** should be considered:

1. Based on the age, physical deterioration and availability of parts for ventilation components, the BEHA strongly recommends that an HVAC engineering firm fully evaluate the ventilation systems throughout the building.
2. Examine the feasibility of repair vs. replacement of univents. Determine if existing vents, ductwork, etc. can be retrofitted for (modern) mechanical ventilation.
3. Examine the feasibility of providing mechanical ventilation to the speech room and the library.
4. Evaluate thermostat settings throughout the school. Thermostats should be set at temperatures to maintain comfort for building occupants.
5. Replace/repair window systems throughout the building -wide to prevent water penetration and drafts through window frames.

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**Picture 1**



**Classroom Univent**



**Picture 2**



**Univent Fresh Air Intake**

**Picxture 3**



**Undercut Coat Closets in Classroom**

**Picture 4**



**Coat Closet Exhaust Vent Obstructed by Box**

**Picture 5**



**Exhaust Cubby Used for Storage**

**Picture 6**



**Light Penetrating around Window That Does not Completely Close**

**Picture 7**



**Efflorescence on Wall in Classroom**

**Picture 8**



**Unvented Kiln in Artroom**

**Picture 9**



**Accumulated Chalk Dust in Classroom**



**Picture 10**



**Exposed Fiberglass Insulation around Pipes in Classroom**

**Picture 11**



**Accumulated Dust and Cobwebs in Classroom**

**Bancroft Elementary School**  
**3 Vinal Street, Auburn, MA**

**Table 1**

**Indoor Air Results**  
**January 7, 2004**

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background (outdoors)	32	22	336	ND	ND	7		-	-	-	Cold, clear skies, sunshine
Girls 3 <sup>rd</sup> Floor Restroom	72	19	873	ND	ND	11	0	Y			No local exhaust, broken toilet seat
Scavone	70	15	635	ND	ND	8	1	Y	Y	Y	Window jammed-open
Music Room	77	19	906	ND	ND	11	25	Y	Y	Y	Dust, DO
11	74	18	1160	ND	ND	16	18	Y	Y	Y	DEM, fiberglass-pipes, cleaning products, TB
10	74	19	1290	ND	ND	23	23	Y	Y	Y	Fiberglass-pipes, DEM, TB, plants, DO, exhaust vent blocked-boxes
13	74	16	1019	ND	ND	14	21	Y	Y	Y	Fiberglass-pipes, DEM, TB, plants, DO, exhaust vent blocked-boxes and other items, dust, accumulated items

ppm = parts per million parts of air  
µg/m3 = microgram per cubic meter

AD = air deodorizer  
AP = air purifier

CD = chalk dust  
DEM = dry erase marker  
DO = door open  
ND = non detect  
PC = photocopier

PF = personal fan  
TB = tennis balls  
UF = upholstered furniture  
UV = univent

**Comfort Guidelines**

Carbon Dioxide - < 600 ppm = preferred  
600 - 800 ppm = acceptable  
> 800 ppm = indicative of ventilation problems  
Temperature - 70 - 78 °F  
Relative Humidity - 40 - 60%

**Bancroft Elementary School**  
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									Supply	Exhaust	
Speech	72	22	1400	ND	ND	15	1	N	N	N	No mechanical ventilation, no openable windows, WD CT-plumbing leak-repaired, recommend installing passive vent in door
Library	73	19	1041	ND	ND	17	0	N	N	N	No mechanical ventilation, no openable windows, recommend installing passive vent in door
Reading Room	72	18	769	ND	ND	11	2	Y	N	N	DEM, DO, CT
Computer Room	71	18	911	ND	ND	11	0	Y	Y	Y	10 (+) computers and related equipment

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